ENERGY MANAGEMENT OF BATTERY TO DC MOTOR

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

An electric vehicle (EV) is vehicles that use an electric as its power source. Electricity can be generate by many ways like solar, wind and water. An EV will produce almost zero emission. An EV used a direct current (DC) motor as exchange with the internal combustion engine (ICE) in conventional vehicle and in hybrid electric vehicle (HEV). A battery electric vehicle (BEV) is just using battery as its power source which is different from HEV that are using ICE as a generator and as a secondary power source that still produce pollution in the air. The energy for BEV is generated by battery to DC motor. This part is known as energy management of battery to DC motor. There is method to estimate the state of charge (SOC) from a battery. In this project, an experiment have be done using 5 horsepower (HP) DC motor and a lead-acid battery to estimate the SOC by using an open circuit voltage (OCV) of a battery. For charging profile, a data is produced by using a 12V 20A charger that is connected to a series of battery. A simulation for determining SOC of a battery to DC motor also have be done by using a MATLAB software version 7.6.0 (R2008a). By an experiment, result of charging and discharging profile are plotted into a graph and by a simulation using MATLAB software, graph of discharging profile is plotted and by analyzed the result, prediction of journey have been made and battery lifetime also can be determined. With this both result, a comparison have been made to both result and an algorithm is been produced consisting of an energy management of a battery to DC motor. With this algorithm, an estimation of the energy left in the batteries that have been supply to different load of DC motor should be easier. The new design of a battery charger also been introduced in this thesis. By using a L200 component, the charger system should be an intelligent circuit with additional features.

ABSTRAK

Kenderaan elektrik (EV) ialah suatu kenderaan yang menggunakan tenaga elektrik sebagai sumber tenaga utama. Tenaga elektrik boleh dihasilkan daripada pelbagai cara seperti tenaga suria, angina dan air. EV hampir tidak mengeluarkan sebarang pencemaran terhadap alam. EV menggunakan motor DC sebagai ganti kepada *internal combustion engine* (ICE) yang digunakan dalam kenderaan konvensional dan kenderaan elektrik hibrid (HEV). Kenderaan elektrik berbateri (BEV) hanya menggunakan bateri sebagai sumber tenaga utama dimana berbeza dengan HEV yang menggunakan ICE sebagai *generator* dan sebagai sumber tenaga kedua yang masih menghasilkan pencemaran di dalam udara. Tenaga di dalam BEV dihasilkan dari bateri ke motor DC. Bahagian ini dikenali sebagai pengurusan tenaga dari bateri ke motor DC. Ada satu cara untuk mengukur *state of charge* (SOC) daripada bateri. Dalam projek ini, satu eksperimen telah dilakukan dengan menggunakan 5 *horsepowe*r (HP) motor DC dan *lead-acid* bateri untuk mengukur SOC melalui *open circuit voltage* (OCV) daripada bateri. Untuk profil mengecas, data diperolehi dengan menggunakan pengecas 12V 20A yang disambungkan kepada satu siri bateri. Simulasi untuk mengukur SOC daripada bateri ke motor DC telah dilakukan menggunakan perisian MATLAB versi 7.6.0 (R2008a). Melalui satu eksperiment, satu keputusan profil pengecasan dan pengediscasan telah dihasilkan dalam satu bentuk graf dan melalui simulasi dengan menggunakan perisian MATLAB, hanya graf pengediscasan dapat dihasilkan dan dengan menganalisa keputusan tersebut, ramalan tentang jarak perjalanan dapat dibuat dan jangka hayat bateri turut dapat ditentukan. Dengan kedua-dua keputusan ini, satu perbandingan telah dilakukan melauli kedua-dua keputusan ini dan satu *algorithm* telah dapat dihasilkan tentang pengurusan tenaga daripada bateri ke motor DC. Dengan terhasilnya *algorithm* ini, pengukuran tenaga yang masih berbaki di dalam bateri yang telah diberi ke bebanan yang berlainan di dalam motor DC sepatutnya menjadi lebih mudah. Rekaan baru sirkit pengecas bateri juga telah diperkenalkan di dalam tesis ini.

Dengan menggunakan komponen L200, system pengecas sepatutnya menjadi sirkit yang pintar dengan penambahan ciri-ciri lain.

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LIST OF SYMBOLS

P_m	Mechanical output power
ω_m	Omega, nominal speed in rad/s
N_m	Nominal speed in rpm
π	Pi, valued at 3.142
K	Constant
T_m	Mechanical load torque

LIST OF ABBREVIATIONS

EV	Electric Vehicle
SOC	State of charge
HEV	Hybrid Electric Vehicle
BEV	Battery Electric Vehicle
ICE	Internal Combustion Engine
AC	Alternating Current
DC	Direct Current
OCV	Open circuit voltage
V	Voltage
R_s	Series resistances
C	Capacitance
R_0	Overvoltage resistance
Pb	Lead metal
PbO_2	Lead (IV) oxide
H_2SO_4	Sulfuric acid
$PbSO_4$	Lead(II) sulfate
H_2O	Water
NiMH	Nickel/metal-hydride
NiOOH	Nickel oxyhydroxide
HP	Horsepower

W	Watt
A	Ampere
Rpm	Rotation per minute
Rad/s	Radian per second
Ah	Ampere-hour
Min/s	Minute/s
SG	Specific gravity

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

An electric vehicle (EV) is the vehicle that use different source of energy from the conventional vehicle. Power source of an EV gained from the electricity to supply the energy to vehicle sub-system. An EV is produce to achieve zero emission vehicles. A conventional vehicle produce a lot of environment pollution and this number are raising rapidly as millions of people gain access to public and personal transportation. Due to the oil price that now is unreasonable raise cause by lack of the petroleum from all over the world, the automobile manufacturers find a ways to using others energy as change to the petrol [1]. One of the energy that have being found is using the electricity since 1931 in Paris [2]. Nowadays, the automobile manufacturers working harder to improve the current EV to become more reliable and have a friendly use functions. Many of the automobile manufacturers have produced an EV such as Daimler-Chrysler, Ford, and General Motors that initially use Plumbum-acid batteries. Toyota and Honda will use nickel metal-hydride batteries and Nissan will demonstrate vehicle using Li-ion batteries as the energy [1]. As in the conventional vehicle, fuel gauge is use to determine fuel left in the vehicle. In EV, the estimation of battery state of charge (SOC) is important to determine the energy left in EV to predict journey that can reach by an EV before empty and need to be charge [3]. Energy from the electricity is supplied by a series of battery pack place in an EV. An EV divided by two categories that are Hybrid Electric Vehicle (HEV) and Battery Electric Vehicle (BEV) [4].

HEV is an electric vehicle using both the petrol or diesel and battery as a power source so hybrid mode can be change anytime necessary. In HEV there are also two kind of HEV. Series HEV and parallel HEV.

Figure 1.1 shows a series HEV. The electric motor will be connecting to drive train and vehicle will driven by electric motor. If the state of charge (SOC) at minimum stage, an Internal Combustion Engine (ICE) will turn on and charging the battery. An ICE will turn off when SOC fully recharge. In SHEV, there is no mechanical connection between ICE and chassis. The advantage of SHEV is the ICE is running at an optimal and combination of speed and torque all the time SHEV being operate. This can reduce the fuel consumption and having a high efficiency. Even though, the SHEV also have a disadvantage. Because of there are two energy conversions install in SHEV, much energy loss due to inner resistance and friction during the transportation of the energy between ICE and wheels [5].

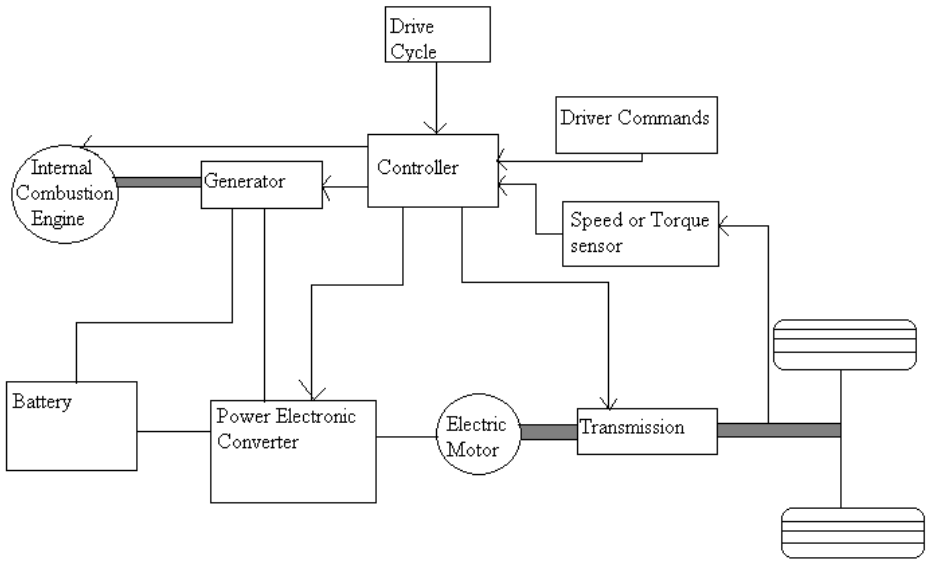

Figure 1.1. Series Hybrid Electric Vehicle [5].

Figure 1.2 shows a parallel HEV (PHEV). PHEV can be driven with both of ICE and electric motor (EM) at the same time. This can make a PHEV to choose the combination freely so the PHEV will be applied by the required torque at each time. To combine these two ICE and EM is to use the EM alone at lower speed and leave ICE to work at high speed so the EM will be more efficient than the ICE. When ICE is in operate mode, an EM will act as a generator and charge the battery. When the power demand is low, only the ICE will be use. When PHEV being accelerated and use high speeds, the EM will be operate as a complement to ICE that will give extra power if needed. An ordinary ICE is inefficient when operate at low speed so better to use EM at low speeds [4].

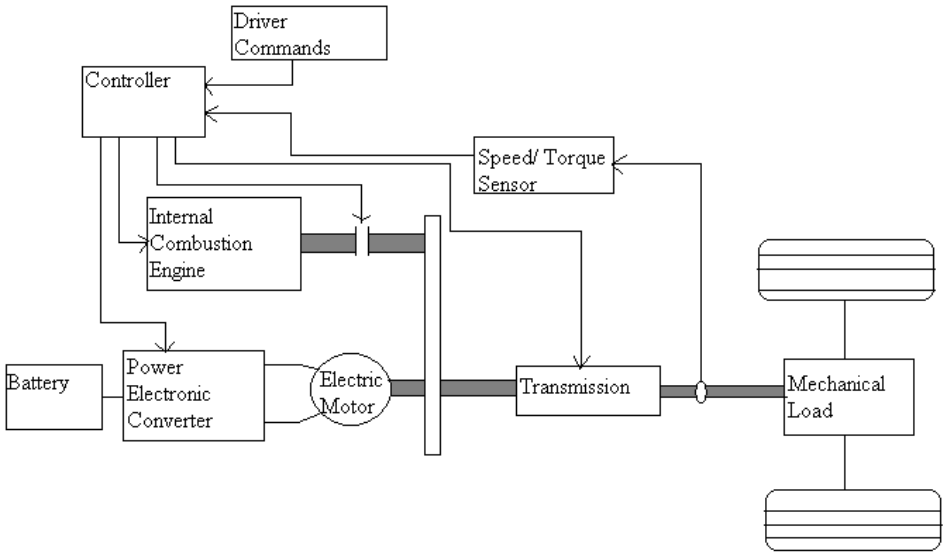

Figure 1.2. Parallel Hybrid Electric Vehicle [4].

Figure 1.3 shows a Battery Electric Vehicle, an EV that using pure electric as a power source. Because of the power source is using 100% energy from the battery, BEV produce zero emission pollution. In BEV, motor will be connecting directly to the drive train. Battery is connected to the motor. Here, if the motor using is from the Alternating Current (AC) motor, BEV will need a Direct Current (DC)/Alternating Current (AC) converter to change the signal from DC to AC so the motor can operate smoothly [6].

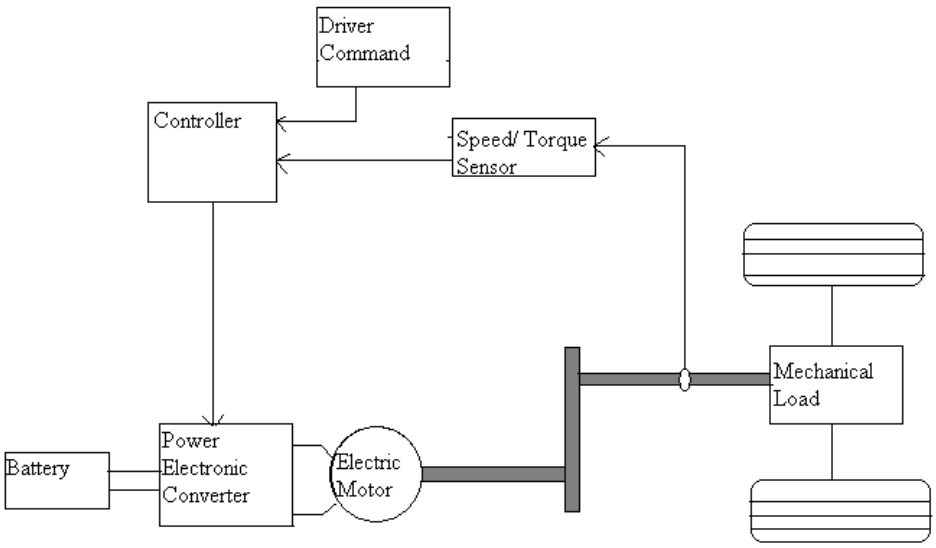

Figure 1.3. Battery Electric Vehicle [6].

1.2 PROJECT BACKGROUND

An EV has not been denied as one of the alternative effort to reduce the environment pollution and cost that cause by a conventional vehicle. For an EV, estimation of SOC is the important subject to be discussed. Methods for estimate SOC have been done by [7] but this estimation is for Hybrid Electric Vehicle. An estimation of SOC for lead-acid batteries also has been done by Ahmad Fasih [8]. Estimation of the SOC for HEV is not a crime but the HEV still producing pollution and using a diesel as its power source. World has tell that the petroleum producing is reducing each year and even each month so, if the method of estimation SOC is for HEV then when the time has come this method is not yet being approve if this method can be use by EV. This thesis will define the energy management of BEV. This thesis want to define if the method of estimation SOC for the HEV can also being applied to the BEV with various type of load use.

1.3 PROJECT OBJECTIVE

The objective of this project is to develop an algorithm for the energy management of Battery to DC motor based on the energy needed by the DC motor.

1.4 PROJECT SCOPE

Objective of this thesis is to develop an algorithm for energy management of BEV. Thus, this thesis will consist:

1) Monitoring the state of charge (SOC) of battery for predictive battery lifetime for different DC motor used.
2) Improving charger system to be more effective.
3) Design intelligent charger controller.

1.5 THESIS OUTLINE

Chapter 1 is about the introduction to the Electric Vehicle that used a DC motor as a replace of an engine in conventional vehicle and the purpose of this thesis written to give an explanation about this project.

Chapter 2 represented the battery modeling, the equation that will use to complete this project and an overview on battery management of electric vehicle. This chapter also will show on how the estimation of Voc and SOC will be determined.

Chapter 3 described the methods that are used to determine the Voc of the battery and from this data, estimation of SOC can be done. This chapter also show the experimental and simulation method.

Chapter 4 shows the result get from both of experiment and simulation method, compared and will be discuss to get the algorithm of energy management of battery to DC motor.

Chapter 5 presents the summary and conclusions to complete this project.

CHAPTER 2

OVERVIEW OF ENERGY MANAGEMENT OF ELECTRIC VEHICLE

From the research, estimation of the SOC is done by using the extended Kalman filter (EKF) for the HEV [7]. So, this project wants to estimate the SOC by different energy of battery and different kind of DC motor by using the experiment and simulation using MATLAB software.

2.1 THE BATTERY

Battery is important in the BEV because it supply the energy to move the vehicle and make it works. Thus, battery management is very important for energy management in BEV.

2.1.1 Battery Management

The automotive is a passive standalone and very important component in the Electric Vehicle (EV). Precise monitoring and active control of the battery are needed in the energy management and powertrain hybridization. The battery monitoring are known as a continuously calculating application-relevant battery state quantities based on sensed physical quantities, typically current, voltage, and temperature. “Configurations of this type have been common for traction batteries for some time, but have more recently been introduced for demanding 12V SLI battery applications as well. Examples for active control measures are state-of-charge (SOC) control by discharge/charge management and thermal management that maintains upper and lower temperature thresholds and limits temperature gradients within the battery.

Together with subsystems involving elements such as sensors, monitoring algorithms, and cooling fans, the battery then forms an energy storage system that interacts with the vehicle in a complex manner". This is meant that state of charge (SOC) is important to determining rate capacity of batteries. The SOC also needed to determining end of the charging and discharging the batteries. To determining the SOC, there are various methods such as direct measurement, specific gravity (SG) measurement, voltage based SOC estimation and also current based SOC estimation. The SOC calculation is important for the batteries in the battery management so the power that will be deliver to the load in the maximum state.

But to determine the state of charge, preferred to use this equation that are determine from estimating the open circuit voltage. That is [1].

$$SOC(\%) = 84 \times OCV - 98.4 \quad (1.1)$$

To make it easier, the table have been develop to determine the SOC much more quicker than using the equation [9]

Table 2.4: Determining SOC base on OCV [9]

Open circuit voltage (OCV)	**State of Charge (SOC)%**
12.6 V	100
12.4 V	75
12.2 V	12.2
12.0 V	12.0
11.9 V	11.9

2.1.2 Battery Modeling

For the simulation of energy consumption of electric vehicles, precise battery models are required. The biggest challenging problem in modeling a battery source is come from the non-linear characteristics of the equivalent circuit parameters that require lengthy experimental and numerical procedures. This is because the battery has its own internal parameter. The battery modeling has 3 basic types of battery modeling. The ideal model of a battery circuit diagram as shown in Figure 2.5 basically ignores the internal parameters and simple where this model is primarily made up of only a voltage source [1].

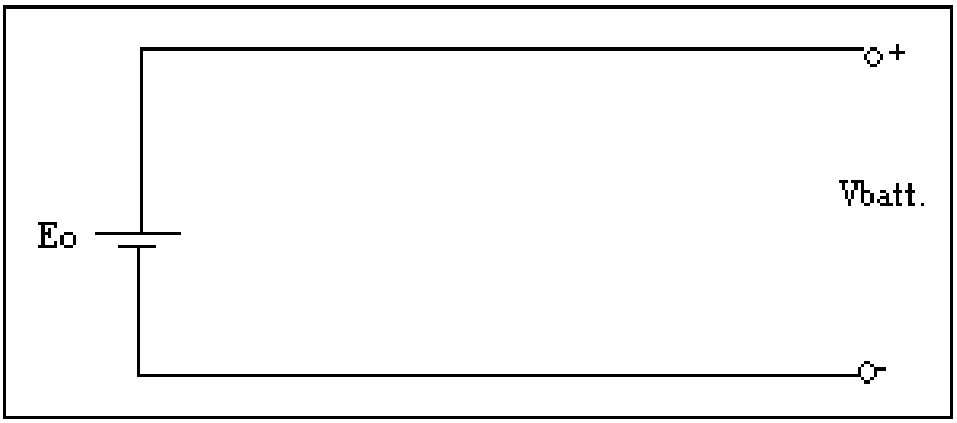

Figure 2.5: The Ideal Battery Model [1].

The circuit diagram as shown in Figure 2.6 is the linear model that is similar to an ideal battery with open-circuit voltage E_0 and equivalent series resistances R_s. The terminal is the V_{batt} and can be obtain from the open-circuit tests. This model is the most commonly used battery model.